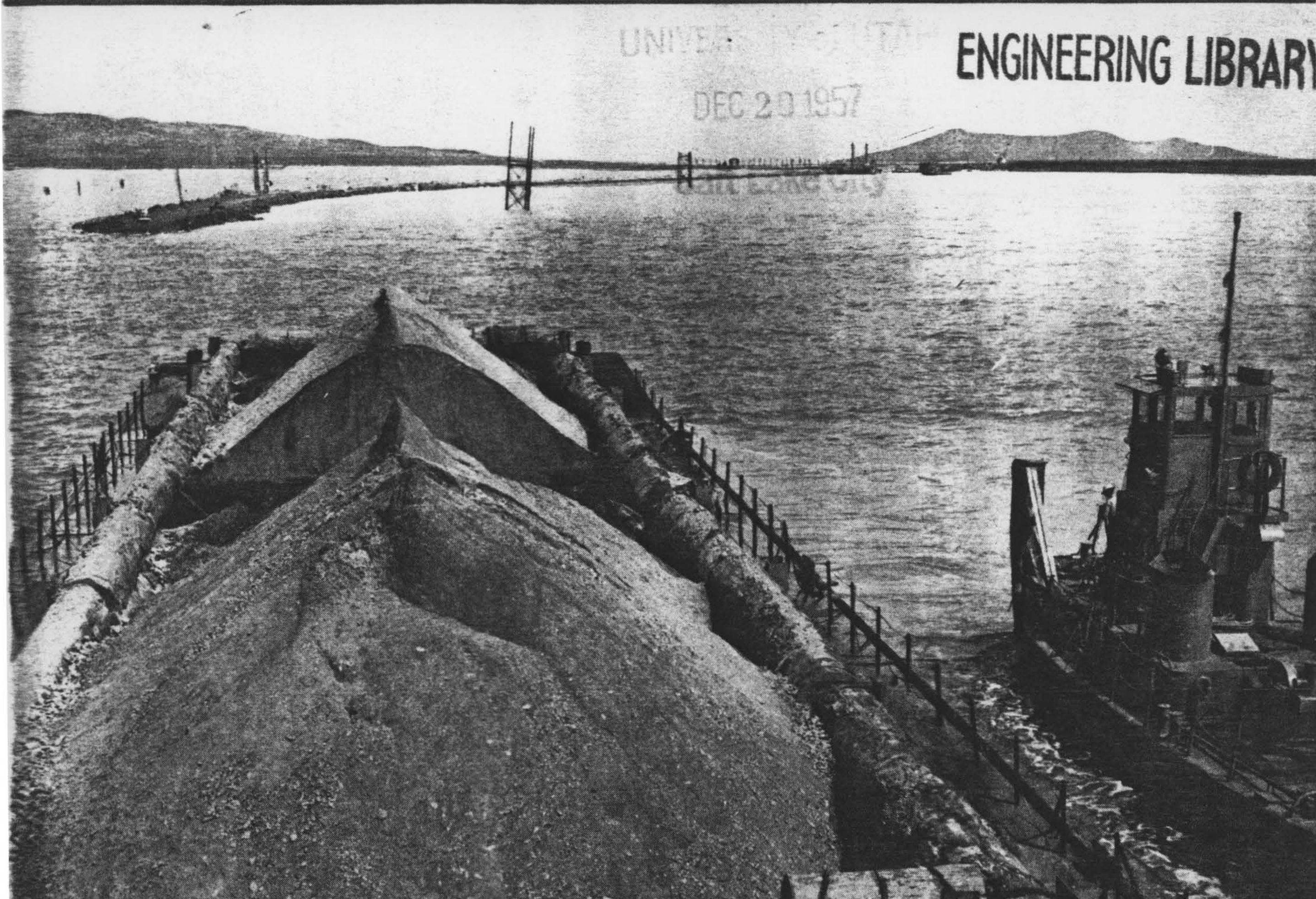
CIVIL ENGINEERING

DECEMBER 1957

THE MAGAZINE OF ENGINEERED CONSTRUCTION



SOUTHERN PACIFIC DUMPS 31 MILLION CUBIC YARDS INTO GREAT SALT LAKE FOR CROSSING.

SEE ARTICLE BY ANDERSON AND JAEKLE

AMERICAN SOCIETY OF CIVIL ENGINEERS FOUNDED 1852

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Great Salt Lake Crossing

New sampler speeds design of

H. V. ANDERSON, J. M. ASCE, International Engineering Company, Inc.,

Planning the new Great Salt Lake crossing of the Southern Pacific Railroad required an extensive study of the existing facilities and their possible future, and a study of the possibility of supporting a fill on the lake-bottom clays. The Swedish foil sampler proved very adaptable in providing undisturbed samples of the clay from which soil-strength characteristics could be determined. Through a series of investigations, it was found feasible to replace the existing trestle with a rock fill.

For many years the Southern Pacific has foreseen the necessity of rebuilding its Great Salt Lake cutoff. In August 1953, it contracted with the International Engineering Co., Inc. (IECO) for a study of the engineering and economic factors involved in the reconstruction or replacement of the crossing. This work included taking undisturbed samples and making foundation borings, laboratory tests, analyses, engineering design, cost estimates, and economic studies.

The early railroad builders avoided the problem of the soft clays in the bottom of Great Salt Lake by building the original route around the north end of the lake instead of across it. Although the advantage of a route across the lake was always realized, it was not until 1902 that the construction of the Lucin Cutoff was finally undertaken. Rock was hauled from quarries at each end until foundation failures of the soft clays halted the operation. Only then did construction of a wooden trestle begin.

Although the lake was no more than 20 to 35 ft deep, wood piles 120 ft long were used for 11,000 ft at the western end and 1,500 ft at the eastern end. The remainder of the trestle rests on shorter piles, driven to refusal on the salt stratum. The 12 miles of wood trestle and the 11 miles of rock fill, comprising the main part of the project, were completed in less than two years. Even making no allowance for the type of equipment available in 1904, this was a construction marvel.

The wood trestle across Great Salt Lake has had a long life. The salt brine of the lake is a natural preservative. No living organism except brine shrimp exists in it. No insect will harm wood that has been immersed in the lake. After continual soaking, wood fibers become hard and brittle and do not decay. Freezing and thawing action is limited. Concentrated salt water has a less corrosive effect on iron than sea water, so the bolts used in the trestle are in much better condition than would normally be expected after fifty years of service.

Despite the preservative effect of the salt, many timber members have had to be replaced. A new deck, helper stringers, and horizontal bracing struts were added between 1920 and 1927. To keep up with the increasing size of trains and freight loads, it has been necessary to strengthen the bents and increase their size. Bracing piles were added from 1943 to 1946 to provide additional longitudinal rigidity.

A fire destroyed 645 ft of double-track trestle in 1956, after construction had started on the new fill. The piles, thought to be fire-resistant as a result of continual soaking with salt water spray, were destroyed as the fire consumed their centers. The bents were rebuilt by placing prefabricated pony-bents on the original piles after the burned upper sections had been sawed off.

The original fills in the lake, dumped on the unstable clay bottom, have required expensive maintenance. The rock fills settled for years after placing. Severe storms, which occur frequently on Great Salt Lake, have subjected the fills to destructive wave action. To prevent water from washing them away, concrete paving was placed over the rock. Finally, huge limestone riprap was built up on the sides. Even though the fill material has been eroded and there are flat slopes below the water surface, which assist in maintaining stability of the riprap, the fills still require maintenance.

Repair or replace is question

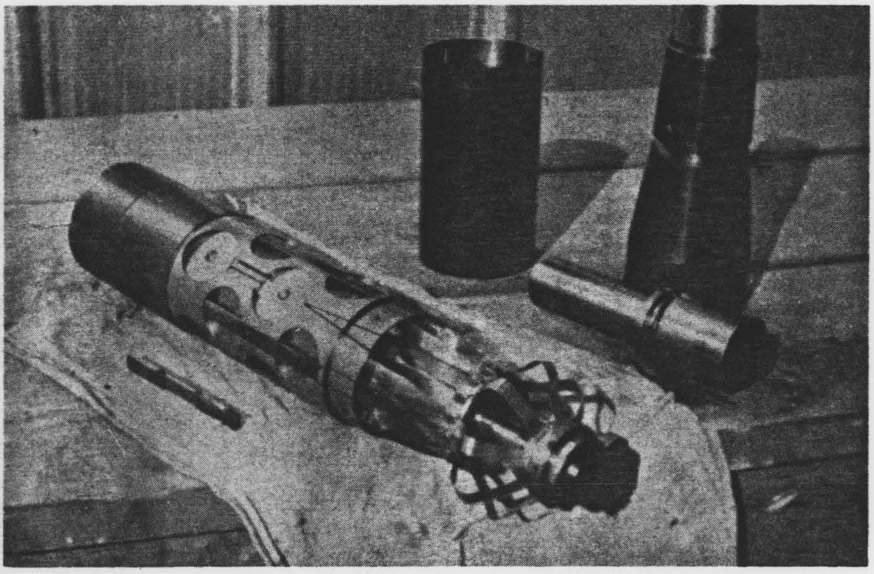
Mounting maintenance costs, the necessity of redecking the existing trestle in the immediate future and about every 25 years thereafter, plus need for the replacement of the timber piling in the next 25 years, dictated a thorough study of the problems and possibilities to find some other means of crossing Great Salt Lake. The following plans were studied:

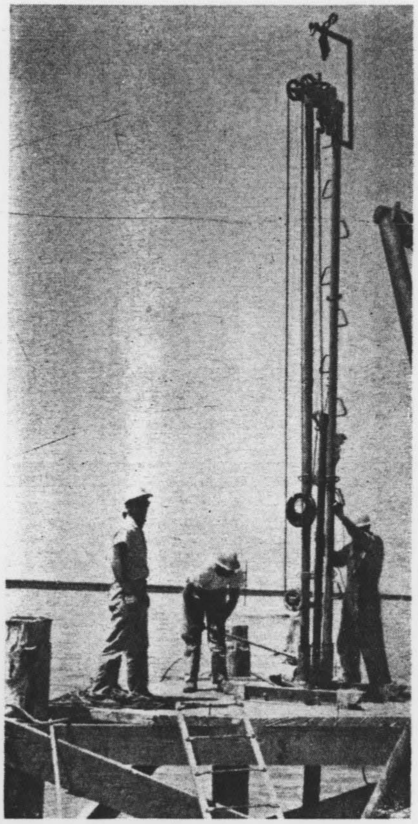
1. Redeck existing trestle and replace with a new trestle after 25 years
2. Reconstruct a new trestle and redeck it after 30 years
3. Construct a new parallel trestle and redeck existing trestle
4. Redeck existing trestle and construct a rock fill after 25 years
5. Construct a rock fill with 3,000 ft of trestle
6. Construct a rock fill with 24,000 ft of new trestle
7. Construct a concrete trestle
8. Build a rock fill 13 miles long

The key factor in determining the most economic means of crossing the lake is the clays which make up the lake bottom and which must provide the foundation for any fill or structure. In the past these clays have been responsible for the settlement of the fill, for slides and slip-outs, and for erosion of the support used for slope protection materials. Failure of these clays to support fill in 1902 resulted

31,000,000-cu yd fill

San Francisco, Calif.





In foil sampler, at left, thin metal foils from reels in head come in contact with soil as it enters sampler and move upward with it as sampler is lowered. This Model VII Swedish sampler is very similar to that used for work described. In view above, foil sampler is forced down into clay by a grip-hoist. Mechanism of sampler includes dial gage, which shows tension on foils, controlled by hand wheel.

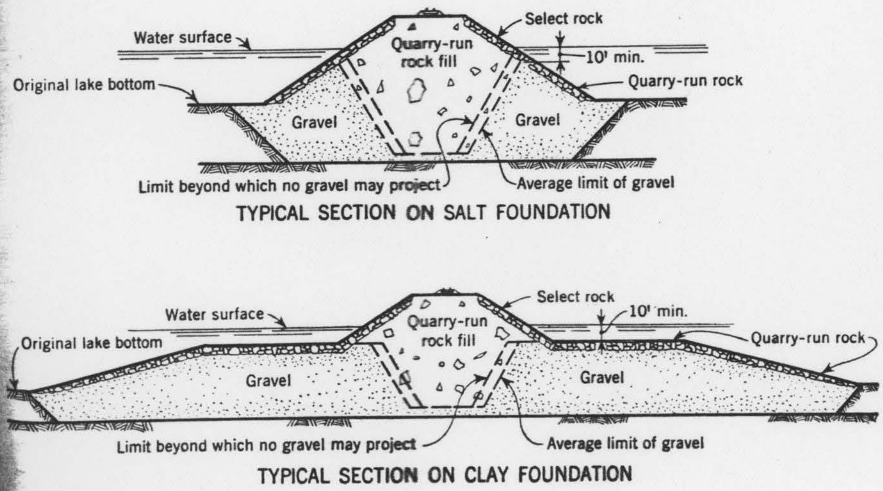
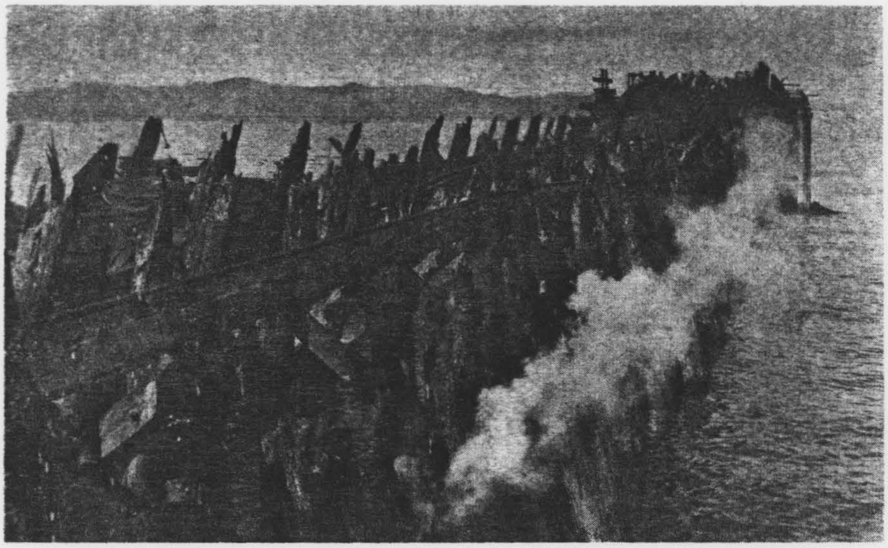


FIG. 1. Gravel blanket up to 400 ft wide helps support rock fill where lake bottom is soft clay. On thick salt layer in center of lake, width of blanket is generally less than 200 ft. Fill has top width of 38 ft and varying depth—about 70 to 75 ft in central section.



Supposedly fire-safe trestle caught fire after work on new fill had started. Railroad and construction crews pooled their efforts to rebuild 645-ft section in one week.

in construction of the costly timber trestle, which is susceptible to fire and earthquake and unsafe for fast freight traffic.

Study of these underlying clays was the first step in determining the probable cost of a crossing. Borings were made through the existing fill at the approaches to the trestle to determine the depth to which the rock had displaced the clay. Undisturbed samples of the consolidated clay were also obtained, using 2½ and 3⅛-in. Shelby tubes. Other samples were taken from the trestle in the center of the lake to provide representative undisturbed clay for the determination of shearing strength.

This preliminary investigation indicated that the foundation clays were suitable for the construction of a "floating" rock fill. However, consolidation was expected to result in 10 ft of settlement of the fill after construction. It was recognized that an extensive investigation of the clay would be required for design purposes if a rock fill were to be built without danger of severe overrun of quantities.

From these studies it was concluded that the annual cost for reconstruction and redecking of wooden trestles would be nearly as much as that for the construction of a rock fill. However other factors, such as a fireproof structure, full-speed train operation, and a permanent facility, made the fill much preferable. See Fig. 1.

In 1954 a seismic survey was made of the proposed crossing by Fisher Research Laboratories for IECO. No subsurface strata of rock were found but the deposit of crystalline Glauber's salt was outlined. This deposit extends across the center of the lake for a distance of some 5 miles.

A hydrographic survey of the proposed crossing was made by IECO in 1955 to determine the economic location for the fill and the approximate quantities of gravel and rock necessary. Borrow sources of fill were located, and topographic maps of the area prepared to aid planning of construction facilities.

In 1955 the underlying salt layer was cored from the trestle at 13 different locations to determine its depth and extent. Vane shear tests of the soft clays were also made from the trestle. Two independent crews of the Selby Drilling Corp. took the samples. One crew used an apparatus designed by the U. S. Bureau of Reclamation, consisting mainly of a gear-reduction drive unit, N-casing, A-rods and the vane. The other crew used an electronic recording vane which eliminated the necessity for a casing but required the use of a Sanborne recorder.

Five permanent platforms were constructed across the lake on the proposed centerline of the fill. It was desirous to work several days at each location and it was found necessary to build permanent platforms. These structures, each 30 ft square, consisted of wooden piling, 12-in. × 18-in. stringers and 4-in. decking. The deck was 10 ft above the water surface for protection from wave action. Vane tests, penetrometer tests, and undisturbed samples were taken at each location. The penetrometer used was an electronically recording device which provided a continuous record of resistance encountered by the piston. The relationship between the results obtained by the vane and those obtained by the penetrometer at platforms No. 1 and No. 2 are shown in Fig. 2.

The Sanborne recording instrument was very susceptible to the salty atmosphere. Because of the operation difficulties of the electronic equipment, the USBR vane shear device was selected for most of the work.

The undisturbed samples were obtained by using a 3-in. Hvorslev piston sampler developed by the USBR. A soils laboratory was set up at the job site, where unconfined compression tests, quick triaxial compression tests, consolidation tests, determinations of water content, density and Atterberg limits were made from the samples. The relationship between the vane tests and the laboratory tests for shear strength is shown in Fig. 3. After a review of the laboratory results, it was decided that unconfined compression tests of carefully taken undisturbed samples would be used for future shear-strength determinations of the foundation clays.

Additional data were needed to assure that the most economically safe section would be selected for crossing the soft clays. A Swedish development, the foil sampler, was used by IECO in 1956 to take continuous undisturbed clay samples up to 50 ft long, of the lake bottom in depths of water up to 35 ft.

The foil sampler

The principle of the new sampler is to insulate the core and protect it from the sampler wall by means of thin axial metal foils. The upper ends of the foils are attached to a piston-brake mechanism above the core. The lower ends unwind from 16 different rolls which are held in the sampler head. As the sampler head advances, the foils are pulled through guides and follow up along the perimeter of the core. The foils not only eliminate the friction produced by sliding but retain the physical properties of each soil layer encountered.

Success of the sampling operation depends upon the contact between core and foils. Since the foils must enter the sample tube at the same rate as the sample, tension on the foils must be applied systematically. This is done by adjusting the level of the piston-brake mechanism. Special measures may also be required for sampling in expansive soils, very soft or very firm cohesive clays, or permeable cohesionless soils.

The sample tubes may be divided into 8-ft sections and transported to the laboratory for immediate testing.

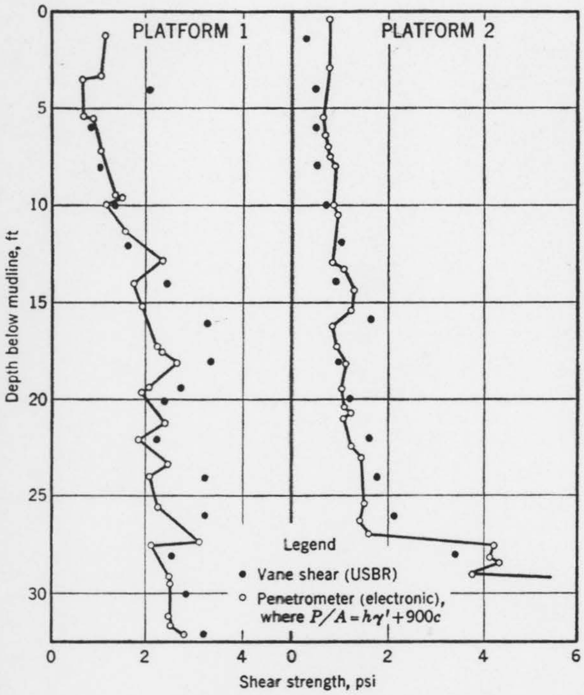


FIG. 2. Shear strengths of clay obtained by U. S. Bur. of Reclamation vane shear device are compared with those by penetrometer.

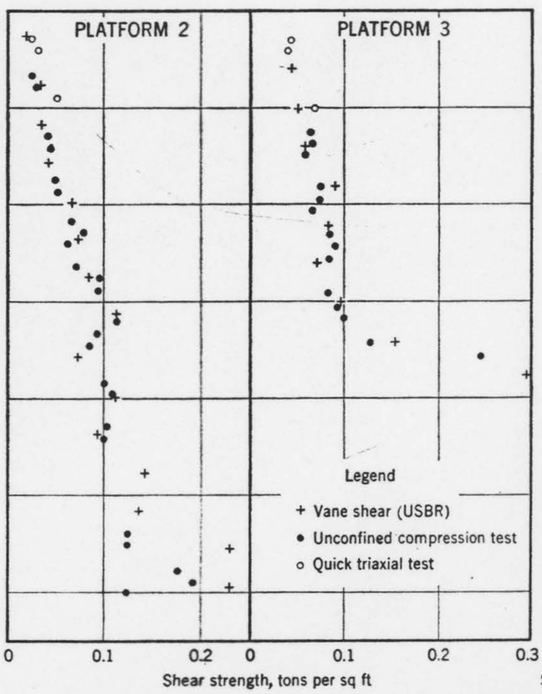


FIG. 3. Shear strengths of clay obtained by vane shear device are compared with the results of laboratory tests.

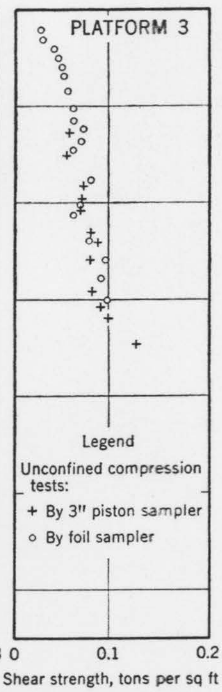


FIG. 4. Two sampling methods yield similar test results.

Extrusion is accomplished by pulling out the foils (and core) into a trough. A thin slice is then peeled off the core the entire length of the sample for purposes of soil classification.

The advantages of the foil sampler are obvious where a complete soil profile is desired. All strata, including void spaces, are disclosed to the soils technician at their exact depth below the ground surface. Permeable layers or hard crusts can also be accurately measured. Disturbed areas sometimes are found in soft layers immediately below a hard layer as a result of the resistance of the hard layer to the cutting edge. With the new samples, such disturbed material can be avoided for testing, and representative samples selected elsewhere.

The quality of the samples proved the feasibility of the sampler, and the number obtained provided its economic justification. No permanent towers were required for the foil-sampler operation as the sampling at each location required only a few hours' work. A portable pipe tripod, 35 ft high with two working decks, was built. After the sampler tower was attached, one continuous sample, 35 ft long, was obtained at each setup. The equipment used included a barge with A-frame and hoist, a tugboat, and the tripod.

Undoubtedly use of the piston-type sampler is economically justified for shallow holes where continuous samples are not required. The average rate, under the same conditions, for a shallow uncased hole using the Hvorslev piston sampler was 10 ft a day. The need for a drill rig to take deep samples increases the cost of conventional piston sampling. Laboratory tests of samples obtained by the use of the foil sampler are compared with those obtained with a piston sampler in Fig. 4.

The test data indicated very low bearing values for the clay soils. But, by removing some 25 ft of valueless mud by dredge and then placing a sand-and-gravel blanket 25 to 40 ft deep over a width of some 400 ft (Fig. 1), a center rock section could be put down that would support the railroad embankment. The fill is being constructed from both ends over clays of low bearing value toward a 5-mile center section which is underlain by the firm, deep bed of Glauber's salt. This will provide time for the fills at each end to consolidate the underlying clays. Little consolidation is expected under the salt layer, and a wide fill section is not necessary to prevent displacement in this area.

Foundation investigations at Great Salt Lake have been very successful in providing the engineer with the reliable information he needs for a safe and economical design. The foil sampler was found to be the most successful device used during the investigations to evaluate the strength characteristics of the clays. IECO's policy is to use engineers to supervise sampling. The foil sampler is regarded not as a contractor's drill machine, but as an engineer's tool of the same importance as the devices used to test and evaluate the sample itself.

Development of sampling technique progressed from the elementary to the technical. Special advisers and consultants were employed as follows. David Piertz, University of California, aided in the design of the electronic devices; and William Holtz, USBR, advised on vane shear testing techniques. Consultants for testing techniques and requirements were Dr. A. Casagrande, M. ASCE, Harvard University; Dr. F. H. Kellogg, M. ASCE, University of Mississippi; R. R. Philippe, Chief, Soils and Cryology Branch, Corps of Engineers; Stanley Wilson, A.M. ASCE, Shannon & Wilson, Seattle, Wash.; and T. Kallstenius, of the Swedish State Geotechnical Institute, one of the inventors of the foil sampler.

The men responsible for the design and construction of the rock fill were William M. Jaekle, M. ASCE, Chief Engineer, Southern Pacific Co., and C. P. Dunn, M. ASCE, President, International Engineering Co., Inc.

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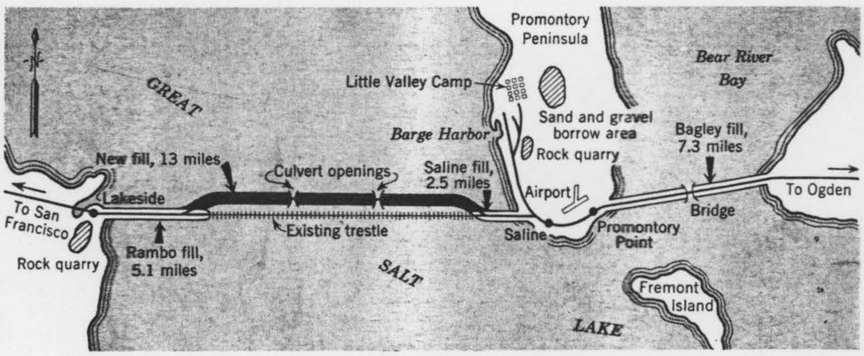
Great Salt Lake Crossing

$49,000,000 project for Southern Pacific

W. M. JAEKLE, M. ASCE Chief Engineer, Southern Pacific Company, San Francisco, Calif.

FIG. 1. In new crossing, three old fills are fully utilized. These are Bagley Fill, Saline Fill, and Rambo Fill, placed in 1902. All sand and gravel comes from one area on Promontory Peninsula. Rock comes also from westerly side of lake.



A mountain of material is being economically moved into Great Salt Lake to put the Southern Pacific Railroad crossing on a completely dependable roadbed. The project entails the dredging of 16 million cu yd of muck from the lake bottom and the dumping of 31.5 million cu yd of rock, sand and gravel. When completed in 1960, the new embankment will measure 12.68 miles long and will have an overall height of 70 to 75 ft and a width of 38 ft at the top and up to 400 ft at the bottom.

All forms of modern earth-moving equipment are used. First a 15-in. and an 18-in. hydraulic dredge take out soft and weak lake-bottom sediments along the line of the new fill. Electric shovels of 8-cu yd capacity load mixed sand and gravel on 27-cu yd bottom-dump trucks. These trucks feed the world's greatest (in terms of tons per hour) belt conveyor to deliver up to 4,200 tons per hour to storage. In a separate operation, additional big shovels load trucks that transfer rock to bottom-dump and flat-deck scows or haul direct to the core of the fill. These are supplemented by side-dump rail cars working from the westerly shore of the lake.

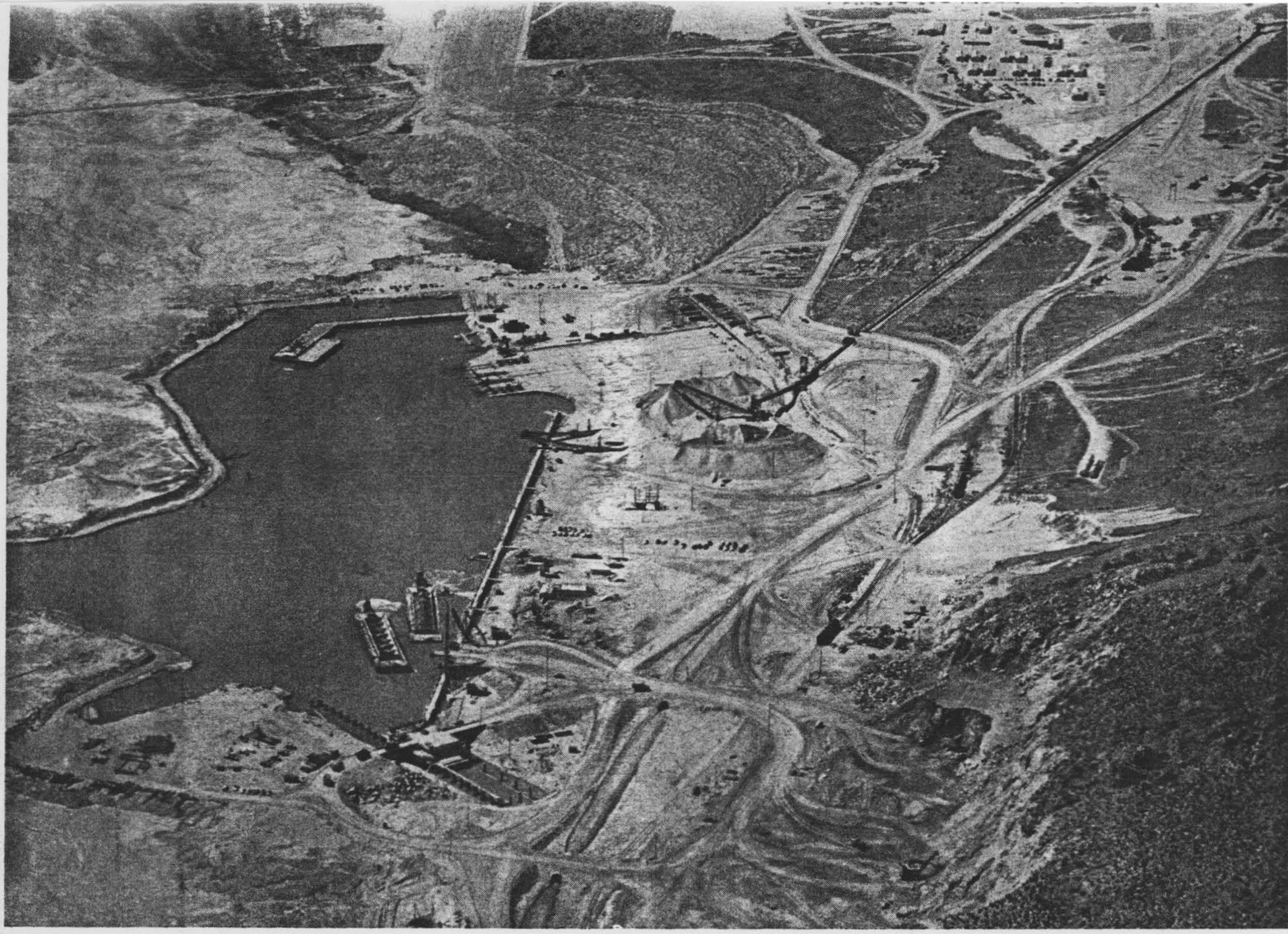
Great Salt Lake, which covers a 2,000-sq mile corner of northern Utah, has long been an obstacle to transportation. In frontier days, wagon trains took a long, tortuous detour to the north. When the rails of the first transcontinental railroad moved closer to a junction from east and west, its builders elected in 1869, to veer north to finish the line rather than try any short cut across the soft clays comprising the bottom of the lake.

The Southern Pacific did tackle the job of crossing Great Salt Lake in 1902, some years after it had taken over the pioneer Central Pacific from San Francisco to Ogden. Under William Hood, M. ASCE, Chief Engineer of the Southern Pacific Co., railroad construction crews set out to build a rock fill as far as practicable across the two major northern arms of the lake. The easterly arm, Bear River Bay, was spanned only after considerable trouble. The exceedingly soft bottom between the west shore and the Promontory Peninsula forced builders to resort to a 12-mile wood-pile trestle to complete the crossing. This crossing shortened the line between Lucin, Nev., and Ogden, Utah, by 43 miles, eliminated 1,500 ft of adverse grades, and cut out 4,000 degrees of curvature.

Freight and passenger trains of the Southern Pacific have been operating across the lake since 1904. But while the lake was bridged, it always remained a problem.

Southern Pacific's present Great Salt Lake crossing project calls for construction of a new rock fill causeway across the deeper part of the lake, spanned now by trestle. The crossing utilizes all the existing embankment. The new fill is being built 1,500 ft north of the wooden structure to keep construction equipment from bumping into the old trestle and possibly interfering with train traffic. The new crossing will be nearly indestructible which will greatly strengthen this transcontinental line—the Overland Route—as a defense artery.

Maintenance costs on the wooden



Harbor and material supply center for Great Salt Lake crossing are located on Promontory Point. Belt conveyor at upper right brings 4,200 tons per hour of sand and gravel to storage near waterfront. Barges secure rock from trucks loaded at principal quarry in foreground. Deck barges are loaded at dock at lower left. Ways where barges were assembled are at upper center, and pier for general service is on far side of basin.

trestle have been mounting steadily under heavier loadings, the wear and stress of the elements, and fifty years of use. To reduce impact and assure safety, trains have been restricted to "slow-order" speeds. Fire or possible sabotage has been an ever-present possibility for the wood structure. The unexpected vulnerability to fire of wood exposed to salt spray for years was demonstrated in May 1956, after work on the new fill was well under way. At that time, 645 ft of trestle was burned out in the first major fire in the history of the Salt Lake cutoff.

Planning for the new work has been under way since 1950. Actual construction started in June 1955, with the dumping of some fill material from railroad cars. Work was accelerated in March 1956 with the award of a $45-million contract to Morrison-Knudsen Co., Inc., of Boise, Idaho.

Installation of railroad track and signal equipment—to be done by Southern Pacific's own forces—will cost about $2 million. With such other expenditures as those for exploration, engineering, testing and overhead, the cost of the project will be about $49 million. However, all construction equipment, valued at $15 million, belongs to the Southern Pacific and will be sold or salvaged for other use.

A construction camp was established two miles north of Promontory Point, close to supplies of rock, sand, and gravel. Included are storehouses, workshops, dining hall, barracks, facilities for 300 family trailers, a supermarket, clothing store, restaurant, post office and school.

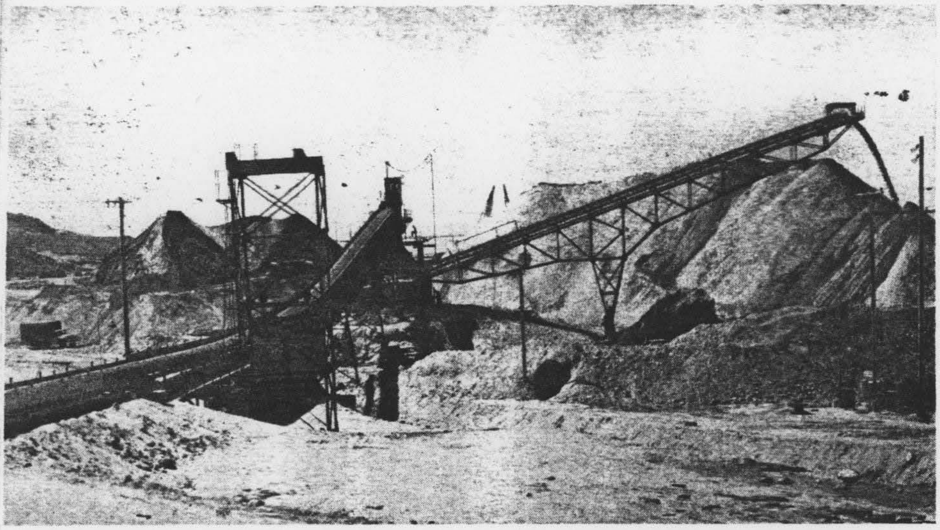
The first major job was the dredging of 1,000,000 cu yd of lake shore to build a half-mile-wide harbor and a channel to deep water 3 miles long and 15 ft deep. Docking and barge-loading facilities were installed by Ben C. Gerwick of San Francisco. A 44-kv power line was brought in from Ogden by Trowbridge & Flynn.

A pocket flotilla of barges, dredges, tugs, and workboats is bearing the brunt of fill construction. It is fed by an unusual aggregation of shovels and trucks, a major part of the material being moved by a most unusual belt conveyer.

All equipment is moved in by rail. Six of the largest bottom-dump barges ever constructed, each capable of holding 2,000 cu yd, were fabricated for the project by Kaiser Steel Co. These were shipped on railroad flatcars in 32 sections, weighing 10 to 30 tons each, for assembly at the site by Chicago Bridge & Iron Co. Five flat-deck barges were built by the Hammond Iron Works at Provo, Utah, to carry about 1,000 cu yd each.

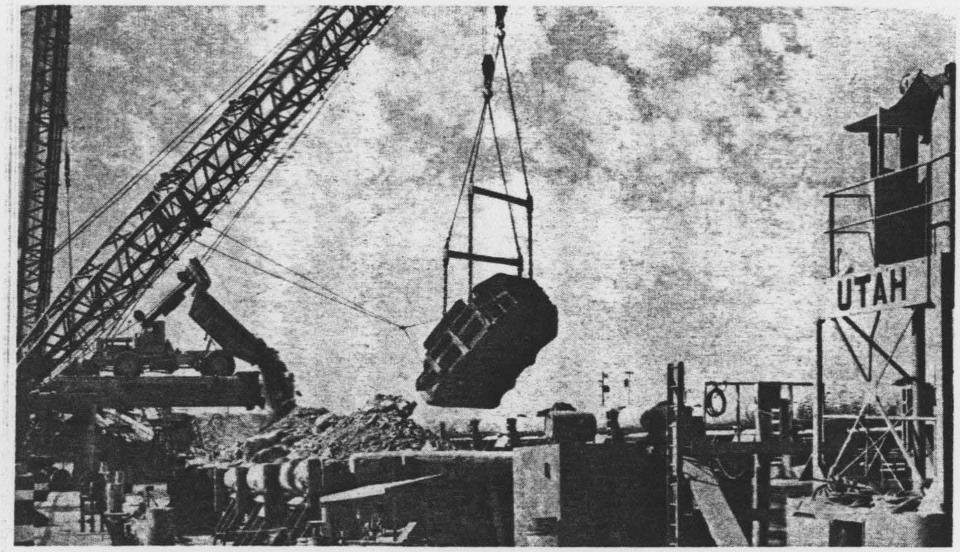
Six tugboats, each equipped with twin 500-hp engines, were built by Gunderson Engineering Co. at Portland, Ore., then halved down the centerline and moved by rail to Great Salt Lake for reassembly and launching. Additional 600-hp tugs handled the flat-deck barges while 300-hp tugs supplemented the larger vessels.

Material for the fill is of two kinds. Gravel, available at lower cost and better for contact with the soft clays, is used for the major part of the fill. Quarry-run crushed stone is used in the center section of the fill to best distribute the load with a minimum of settlement. Selected large rock from

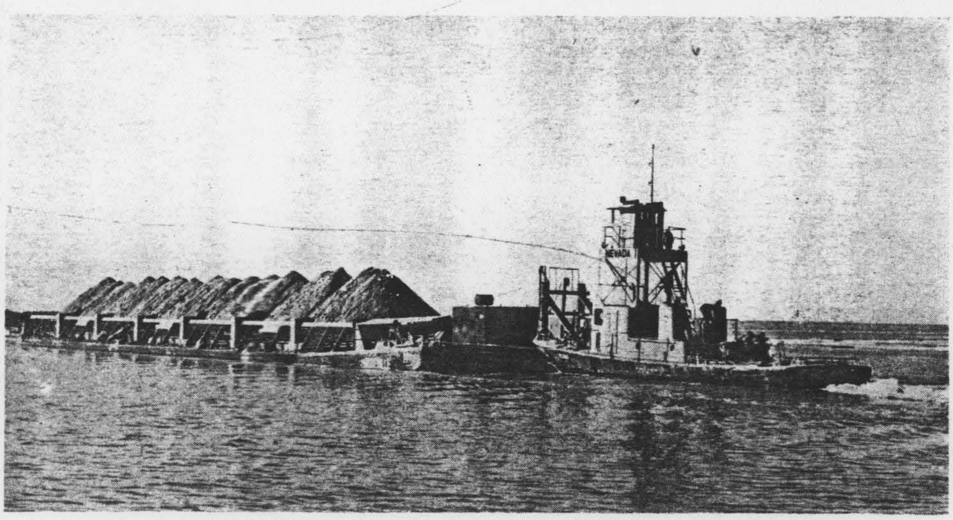


At left: Stacker builds stockpile 70 ft high over two reclaiming tunnels. Stacker in turn is fed by conveyor 7,500 ft long, which delivers 4,500 tons of sand and gravel per hour.

Derrick in foreground places layer of rock over bottom-dump gates of barge ahead of general loading by dumping from trucks, seen under way in background.



Major part of $49 million crossing is underwater fill. Barge of 2,000-cu yd capacity has seven hoppers that can be dumped singly or together by remote control from tug.



the quarry is used for a blanket over the gravel fill and for riprap on the slopes.

Sand and gravel come from a range of hills some two miles from the lake and about 400 ft above it. Blasting is not necessary. Three 8-cu yd electric shovels load a fleet of 11 bottom-dump trucks for a short haul to a dumping station over the high-capacity belt conveyor. The sand and gravel, with plus 8-in. material scalped out and crushed, is loaded on the 54-in.-wide belt that travels at the unusual speed of 850 fpm. Accelerating belts, 30 ft long and 60 in. wide, operating at 500 fpm, reduce stress and wear at the loading point and at the one transfer point required. This "dog-leg" conveyor system carries the materials 7,500 ft to a radial stacker near the barge harbor. The main conveyor has a regenerative braking system that produces power as it controls the 400-ft downward component of material moving at the rate of 4,000 tons per hour. Electricity is fed into the job power system.

In a recent 30-day period, the belt delivered an average of 83,333 tons a day, with surges as high as 5,000 tons an hour.

The stacker at the waterfront is used to build a semicircular stock pile of 70,000-cu yd capacity over two tunnels made from Armco Multi-Plate pipe of 180-in. diameter. Each tunnel has five openings for reclaiming material. A 72-in.-wide conveyor in each tunnel delivers the gravel at a combined rate of 12,000 tons per hour, sufficient to load a barge of 2,000-cu yd capacity in fifteen minutes. When the material is moist, loading takes appreciably longer.

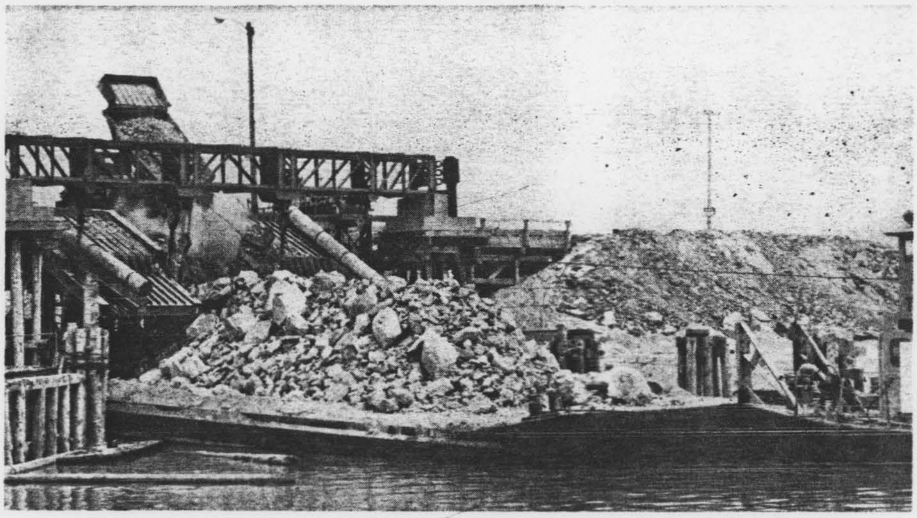
The crushed stone and riprap come from a quarry where very large blasts have been used. The largest was the detonation of 1.8 million lb of explosives at Little Valley on July 21, 1957. About 3 million tons of quartzite rock were obtained from this one blast. The stone is hauled by end-dump truck to the harbor, where it is loaded into bottom-dump barges or on flat-deck scows. The hopper barges are loaded by first lowering material in skip buckets to provide a cushion and then dumping from the dock.

Meanwhile in the lake, the 15-in. and 18-in. dredges have excavated a trench in which the material is to be placed. A wide area is excavated and replaced with gravel fill, requiring some 400 to 500 cu yd per lin ft. Dredges work some 2,000 ft ahead of the fill operation, about the minimum distance permissible with equipment that can place as much as 50,000 cu yd per day.

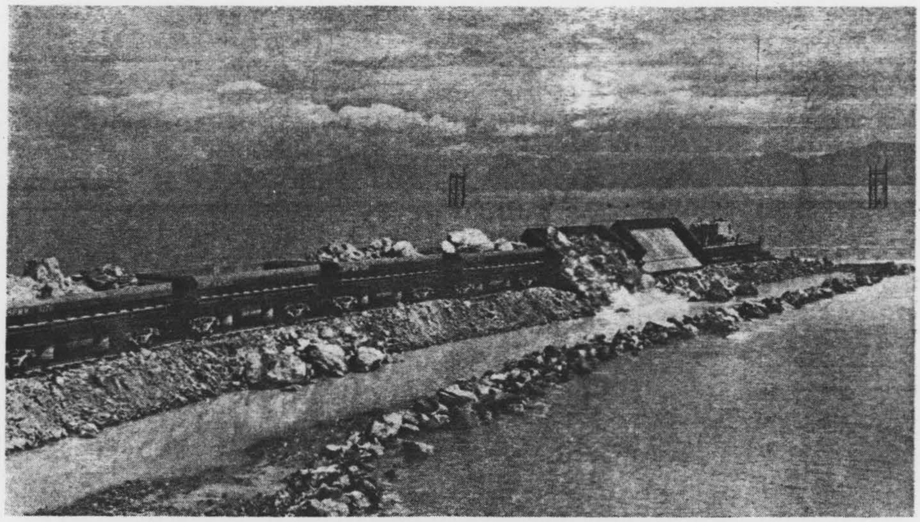
The bottom-dump barges are positioned over the trench and dumped by remote control from the bridge of the tug. Each barge has seven hoppers that can be opened all together or individually. Profile of the underwater fill is checked daily, or after each dumping if necessary, by an electric fathometer mounted in a small boat. The bottom-dump barges have a draft of 11 ft so cannot be used when the fill comes within 12 to 15 ft of the surface. For this work the flat-deck barges are used; they are unloaded by tractors that push the material over the side. This procedure is supplemented by direct truck-haul operations at the east end of the project and by train haul with side-dump cars from the western end.

The fill is being placed from both ends toward the middle section founded on the rock salt formation. Two years are expected to elapse between completion of the end and mid-portions of the fill. There is much work yet to be done before trains can maintain full speed across Great Salt Lake. Unit costs of fill are given in Table I.

Technical phases of the operation are being handled by International Engineering Company under the direction of President C. W. Dunn and Chief Engineer T. Mundal, M. ASCE. H. V. Anderson, J. M. ASCE, has directed field sampling, testing and development of engineering data and design. Construction Division Engineer H. J. Willard and Engineer Inspector J. C. Strong, J. M. ASCE, have been active in coordinating the work of the contractor with that of the International Engineering Company for Southern Pacific.



Above: Rock is dumped down skids which are adjustable for height to prevent damage to flat-deck barge. Tractors shove rock off barge to build upper part of fill. Below: Work train of air-dump cars unloads rock at westerly end of fill project. Next, bulldozers will move in to push rock ahead and out over gravel blanket. Blanket was placed first, by bottom-dump barges, to within 12 to 15 ft of water surface, in trench provided by dredging.



Since 1904, Southern Pacific trains have passed over this 12-mile-long timber trestle on their way across Great Salt Lake. High salt content of lake water preserves the wood and damages iron fastenings less than would sea water.

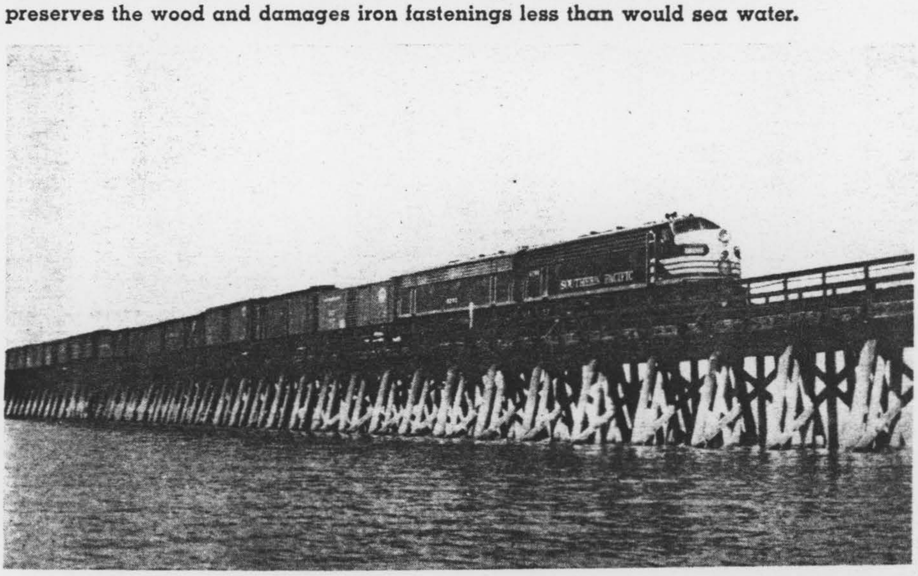


TABLE I. Unit cost of fill across Great Salt Lake

Operation cost only, not including purchase of equipment, plant installation, and overhead

Item	Cost per cu yd
Dredging	10.5 cents
Gravel fill by bottom-dump barge	39 cents
Rock fill by bottom-dump barge	75 cents
Rock fill by flat-deck barge	90 cents
Truck haul to fill, rock	90 cents
Train haul to fill, rock	67 cents